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Future of renewable energies in Iran

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Abstract

The activities in field of renewable energy in Iran are focused on scientific and research aspects, and research part is aimed at reduction of capital required for exploitation of related resources. The second step is to work research results into scientific dimension of this field for practical means, i.e. establishing electricity power plants. Due to recent advancements in wind energy, many investors in the country have become interested in investing in this type of energy. At the moment, projects assuming 130 MW of wind power plants are underway, of which, 25 MW is operational. Based on the planning in the 4th Socioeconomic and Cultural Development Plan (2005–2010), private sector is expected to have a share of at least 270 MW in renewable energies. However, it is the government's duty to take the first step for investment in biomass and solar power plants; private sector may then play its part once the infrastructures to this end are laid out. At the moment, a 250 kW plant is under construction in Shiraz and two more geothermal units with 5 and 50 MW capacities will follow. Moreover, two biomass and solar energy plants, standing at 10 and 17 MW, respectively, are of other upcoming projects. The project of Iran's renewable energy, aims to accelerate the sustainable development of wind energy through investment and removal of barriers. This preparatory project is funded by the global environment facility (GEF) and will provide for a number of international and national consultant missions and studies. Once the studies are concluded, a project to develop 25 MW of wind energy in the Manjil region of Gilan will be prepared. It will be consistent with the national development frameworks and objectives and form part of 100 MW of wind-powered energy, which is expected to be developed under the government's third 5-year national development plan (started 21 March 2000).

Keywords: Renewable energy; Electricity; Sustainable development

Contents

1. Introduction

In general terms, energy sources are classified as renewable and non-renewable energy types. Renewable energy is fuelled by a resource that is sustainable in economic, social and environmental terms .It is usually defined by the fuel source, for example, solar, wind, biomass, tidal, etc., but it has other relevant characteristics that are important. Renewable energy has the capacity to provide cost-effective energy to remote

Abbreviations: SCN, site code number; *W*, prevailing wind speed (m/s); WD, direction of prevailing wind speed (°); NS, number of sites; TC, nominal turbine capacity (kW); NT, number of turbines; *U*, wind speed at hub height (m/s); *E*, energy production (W/m^2); TNC, total nominal capacity (MW); AEP, annual energy production (GW/year); SA, site area (km^2); PD, power density (MW/km^2); ED, energy density (GWh/(year km^2)); CRERA, Center of Renewable Energy Research and Application.

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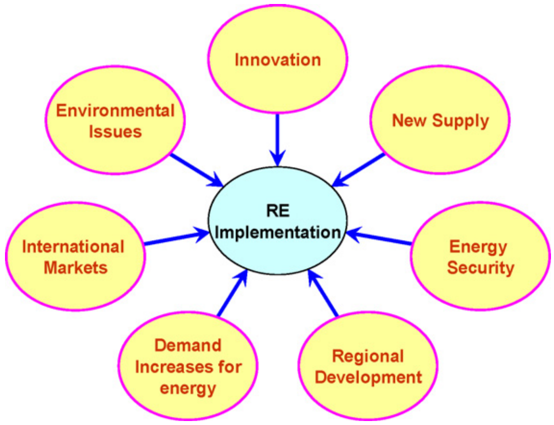

Fig. 1. Key drivers for renewable energy in developing economies.

communities without the added investment of providing fossil generation. The challenge for renewable is great. In the last 25 years 1.3 billion people living in developing countries have gained access to electricity, but population has increased by 2 billion in the same period so there are 700 million more people without electricity than was the case 25 years ago. Because of the remoteness, cost and demographics the grid will never reach most of them, and this suggests that Remote Area Power Systems (RAPS) are then, likely to be the only way of supplying power to them. The degree to which such efforts will be successful will be driven in part by the existence of renewable resources and reliable cost-effective technology. Success will also depend on good policy decisions being made. In many cases compromises are required since options are mutually exclusive. In other cases, carefully considered policy can minimize the conflict between renewable and non-renewable energy. Some of the drivers that policy-makers and implementers need to consider when renewable energy can potentially deliver cost-effective power to communities are shown in Fig. 1. It should be noted that all the drivers are not same in every type of economies [1]. The status of electricity generation from renewables by the year 1994 and share of each source is shown in Table 2. In case of Iran there is a strong political will to develop the renewable energy resources and harness the potentials. Installed capacity and production electricity energy per year from renewable energies in Iran has been indicated in Table 1. Therefore, the energy resources investigated and applied in Iran are wind power, solar, thermal, geothermal, photovoltaic, biomass, biogas, hydrogen energy and fuel cell.

The strategy of harnessing some of renewable during the third 5-year national plan is shown in Table 2.

Table 1
Electricity from renewable energy in Iran (WEC 2005)

	Installed capacity (MW)	Production per year (GWh/year)
Geothermal	55	410
Wind	47.58	71
Solar	53	–
Total	155.58	–

Table 2
Renewable energy strategies during third 5-year national plan

	Unit	2000	2001	2002	2003	2004	Total
Mini hydral	MW	4.9	4.14	6.25	15.5	23.5	54.3
Wind power	MW	2	24	36	43	3	111
Solar water heater	m^2	800	1000	1500	1700	2000	7000

2. Materials and methods

2.1. Wind potential

Wind or air motion comes from temperature gradient between two or more regions. Application of wind energy goes back to thousands of years, but its application to generate electricity was made prevalent in last century. The early provision of natural power to replace or augment human and animal muscle power came from the widespread use of sail wind mills and water wheels of various designs used for grinding grain and for pumping irrigation water. Such installations can be found from Egypt in the middle east across Mesopotamia and Iran to China in the far east [2].

Wind power is still used for pumping water, irrigating the farm lands and grinding the food grains in addition to generation of electricity. Wind turbines do not need fossil fuels and therefore do not release polluting gases into environment. The wind turbines and the accessible roads occupy only less than 1% of the total area of a wind site. So, it is possible to use the rest 99% of the area for cattle grazing or cultivation if necessary. The wind power turbines can produce electricity when only there is enough wind. Besides this, the quantity of electricity generation varies with the intensity of wind flow. The manufacturers of wind turbines can design and produce their products according to the environmental specific conditions for example, for low wind flow regions, a type of wind turbine has been made that its rotors are larger than the generator. These systems can gain the peak electricity generation with relatively low wind velocity, though they lose some of the high velocity wind potentials. In an study the preconditions for installing wind turbines has been listed as follows:

- political willingness,
- good wind conditions,
- available and accessible land, and
- available utility grid.

It has been made clear that the possibilities for wind power in Iran are extremely good and all the above conditions are fulfilled. It has been therefore suggested that wind power is an important factor in the electricity production and 100–300 wind turbines can be installed at each wind farm location. This wind farm would then in reality function as a power plant. By putting up such wind farms at different locations in the country, the electricity production would become more decentralized and saving environment from the damaging pollution from burning traditional fossil fuels. The investigations and the research projects conducted so far to estimate the wind potentials

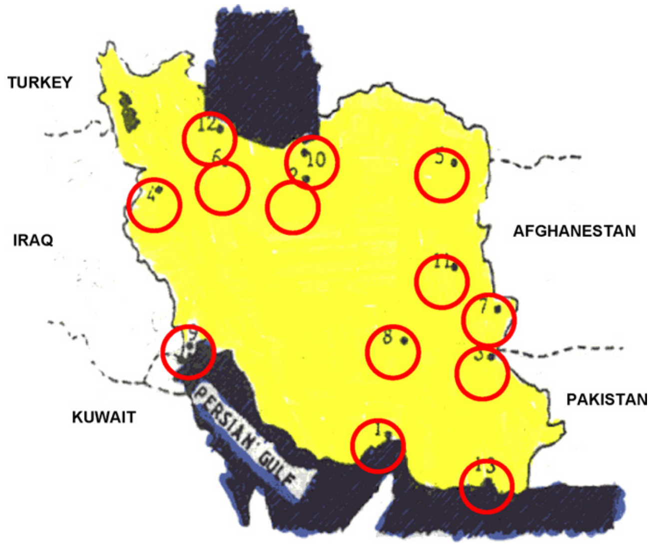

Fig. 2. The selected sites for investigation.

include 26 regions and 45 sites in Iran. The results indicate that though in general the country falls in medium wind velocity regions of the world, but in some of the regions, continuous winds with suitable velocity exists which are capable of generating electricity. In one of the research projects, a mathematical model was engaged to assess wind energy resources on selected sites potentially suitable for wind energy applications in Iran [3]. This research work resulted in estimation of the average yearly energy production of an appropriate wind turbine for 13 selected locations, the site numbers are indicated in Fig. 2. Table 3 also shows the site code numbers for these locations.

Situation of wind power plant projects in several provinces in Iran is indicated in Table 4. Also specifications of wind turbines for various sites are described in Table 5. Table 6 shows electricity production for several sites in Iran from 1997 until 2006.

Figs. 3 and 4 show installed wind power plant and electricity generation at Manjil (Iran) which is important location for electricity production from wind power. Table 7 shows specifications of observation and executive programs for wind power in Iran.

Table 3
Site code numbers for each location

SCN	Location
1	Bandar-Abbas
2	Semnan
3	Zahedan
4	Sanandaj
5	Torbat-H.
6	Ghazvin
7	Zabol
8	Kerman
9	Abadan
10	Babolsar
11	Birjand
12	Rasht
13	Chabahar

Table 4
Situation of wind power plant projects in several provinces in Iran

Province	Operation specification		Executive specification	
	No.	Capacity (MW)	No.	Capacity (MW)
Gilan	70	34	1	0.01
Ghazvin	–	–	40	26
Khorasan	22	13	24	15
East Azarbayjan	–	–	1	0.01
Total	92	47		

Table 5
Specifications of wind turbines for various sites in Iran

Site	Province	Township	Installed turbines	
			No.	Capacity (MW)
Rudbar	Gilan	Rudbar	4	2.15
Manjil	Gilan	Manjil	31	13.25
Paskulan	Gilan	Manjil	22	14.52
Harzvil	Gilan	Manjil	12	3.6
Babaian	Gilan	Manjil	1	0.6
Binalud	Khorasan	Binalud	20	13.2
Ventis Dizbad	Khorasan	Mashad	2	0.26
Total	–	–	92	47.58

Table 6
Electricity generation from several wind power plants

Year	Nominal capacity (MW)	No. of turbines	Specific production (MWh)
1997	1	2	4238
1998	3.95	11	6766.805
1999	9.9	25	17592.693
2000	10.8	28	35044.075
2001	10.8	28	36541.568
2002	10.8	28	33656.112
2003	11.4	29	30281.306
2004	16.85	43	27621.023
2005	24.88	56	46511.471
2006	47.58	92	70902.196

3. Solar energy potential

Although use of solar energy in its direct and indirect forms can be traced back to many ancient civilizations, it is still reasonable to say that the technological harnessing of this environmentally benign energy source has occurred only over the last four decades of this century. Early use of solar energy has been attributed to Hero Alexandria and the ancient civilizations of the Mediterranean region that understood fully and applied effectively the basic principles of solar efficient architecture. This can be sect especially in Greek and Roman building which incorporated the solar design feature first enunciated by Greek philosophers [2]. For the cities situated in the desert, the annual solar radiation and daily sunshine hours is much more than the averages mentioned here. The CRERA-

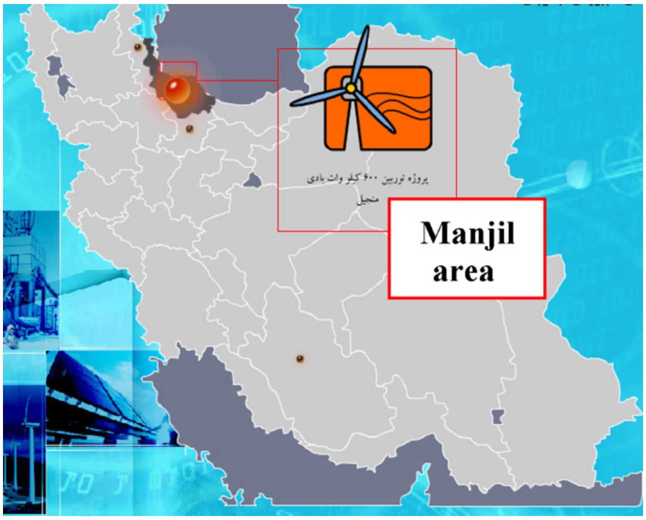

Fig. 3. Wind power plant installed at Manjil.

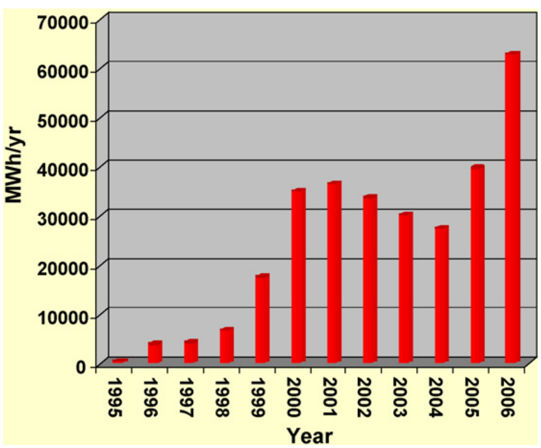

Fig. 4. Electricity generation from Manjil wind power plant.

AEOI so far has conducted and completed many research projects in the area of solar energy. The design and simulation of solar water pumps, solar water distillation of various types, design, manufacture and simulation of solar collectors of different types, solar refrigerator and design and manufacture of solar air heaters are some of the examples.

Similar projects are also done by some universities, research institutions, and also research center of the Ministry of energy on solar energy. Table 8 shows the solar energy projects completed or near completion. The projects to be completed during the third 5-year plan are off-grid photo voltaic (PV) systems and solar water heaters. Both AEOI and Ministry of Energy are working on PV projects and solar systems. Water heaters of the flat types are designed and manufactured by Ministry of Energy. Shiraz power plant is shown in Fig. 5.

Table 9 shows electricity production for several sites in Iran from 1998 until 2006.

Table 7
Specifications of observation and executive programs for wind power in Iran

Project	Region	Utilize	Capacity (MW)	Production of energy every year (GWh)
Turbine Sahand	Azarbayjan	2007	0.01	0.25
Binalud power plant	Khorasan	2005	28.4	124
Vahidi turbine	Bojnurd	2007	0.06	–
Movahed turbine	Gilan	2007	0.01	–
Wind power plant	Gilan	2009	60	190
Wind turbine	Gilan	2007	90	200–330

4. Geothermal power potential

Due to decomposition of the internal earth's crust elements, huge amount of heat is produced. At the most subterranean layers of the earth, temperature increases so high that stones and soils are melted. If underground flowing water passes in close vicinity, it becomes hot. The water temperature sometimes even rises up to 150 °C (300 °F). When this hot water reaches the earth surface from crevices, it is called ''Geyser''. In most cases, lot of vapor also leaves the earth surface along with the hot water. Geothermal resources is not same everywhere and these resources mostly exist wherever there is a volcano. One of the methods of using the geothermal energy directly is house heating and also heating the greenhouses. This method is mostly used in the countries like Hungary and Italy. Another way of using this energy is generation of electricity. Very hot water and vapor is pumped and transferred to power plants through pipelines to start rotating and keep on moving turbines. Some of the countries such as New Zealand, America, Japan, Iceland, Turkey, Indonesia, China, etc., have built power plants to generate electricity from geothermal energy. Although the geothermal energy, with its 0.3% compared to the total electricity produced world wide plays a very minor role on the world energy scene, but compared to other renewable energy sources it ranks first (Table 1). The forecasts of geothermal power were supposed to be at 11025.8 MW [4]. Results indicate that Iran has substantial geothermal potential in the north and northern provinces and there are several hot water springs, the temperature of some of which reaches to 85 °C. Company (ENEL) suggests that Sabalan (Booshli), Sehand, Damavand, Maku–Khoy and Sareine regions have promising prospects for electrical generation (Table 10). The Center of Renewable Energy Research and Application (CRERA)-AEOI, and Ministry of Energy are investigating these regions in detail to harness this type of energy [5]. The Meshkinshahr area in Sabalan region has been selected for the first exploration drilling site (Fig. 6). The maximum temperature of local thermal springs is 83.5 °C. The geothermometry has been attempted the investigations carried out by an Italian and best estimates are in excess of 150 °C in deep wells. Similar investigations approved 10 more potentially suitable regions for this purpose in other parts of Iran. The Electric Power Research Center (EPRC) and Renewable Energy Organization of Iran (SUNA) were established to justify priorities of the above-mentioned regions [6]. Fig. 7 shows geothermal prospects of Iran.

Since Iran is a developing country with an increasing rate of electricity of consumption, in order to secure the supply of

Table 8
The solar energy projects completed or near completion

Project	Type of technology	State	Condition of completion	Capacity (kW)	Grid type	User
Solar power plant	PV	Semnan	Completed	27	Off-grid	AEOI
Solar power plant	PV	Yazd	”	5	Off-grid	”
Development of solar power plant	PV	Semnan	”	92	Off-grid	”
Development of solar power plant	PV	Yazd	”	12	Off-grid	”
Solar lighting	PV	Tehran	”	0.45	Off-grid	Ministry of Energy
Photovoltaic pump	PV	Tehran	”	–	Off-grid	Ministry of Internal affairs
Photovoltaic	PV	Khorasan	Under completion	3.5	Off-grid	Shiraz
Shiraz power plant	Solar thermal	Fars	”	250	Off-grid	University/Ministry of Energy
Receiver system	Solar thermal	Tehran	”	1000	Off-grid	Ministry of Energy
Photovoltaic	PV	Tehran	”	4.5	Off-grid	Ministry of Energy

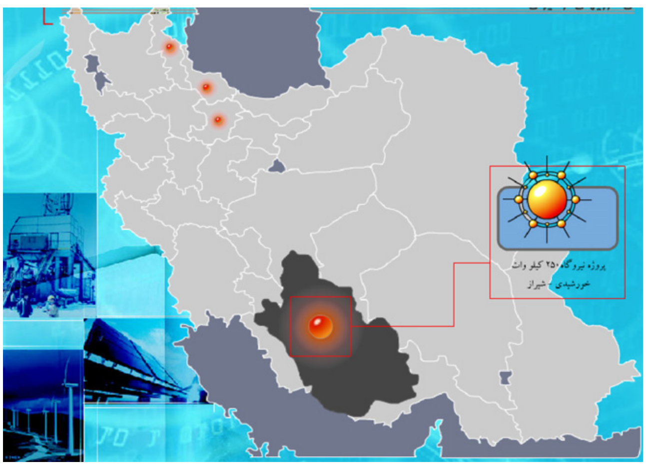

Fig. 5. Shiraz power plant.

electrical energy, estimated at a growth rate of 3000 MW/year, in future renewable energy in general and geothermal energy in particular should play an important role to help the sustainable development of the country. In the long-term, geothermal energy will remain a viable option to furnish clean, reliable power in Iran. Geothermal development offers a viable energy alternation to fossil fuel, though environmental and social impacts of geothermal development must be carefully a properly managed. With the experience of Meshkinshahr we can write our scenario for the future and define new projects for

Table 9
Electricity generation from several solar power plants

Year	5 kW photovoltaic (MWh)	30 kW photovoltaic (MWh)	Darbid Yazd & SarKavir Semnan power plants (MWh)
1998	–	–	12
1999	–	–	21
2000	–	–	20
2001	–	–	85.4
2002	–	–	110.1
2003	1.5	22	25.6
2004	2.2	45	74.25
2005	3	45	92.2
2006	–	10	43
Total (MWh)	6.7	122	483.55

developing a geothermal industry in Iran. Some well are drilled in Meshkinshahr field. Data are gathered during drilling and flow testing. The early results allow undertaking a volumetric stored heat calculation, which will provide an indication of the resource potential [6]. There are many balneology places and tourism attractions in the Sarain area, which is located in the province of Azarbayjan. Meshkinshahr and Sarain are in the Sabalan region and the outlet of the Meshkinshahr power plant and new wells in Sarain could give us sufficient energy for direct use of geothermal energy in tourism attractions in

Table 10
Different potentially geothermal regions investigated north and northwest Iran

S. no.	Region	Estimated thermal energy ($\times 10^{18}$ J)	Estimated mean reservoir temperature (°C)	Reservoir depth (m)	Region area (km^2)
1	Meshkinshahr	14.84	240	2000–3000	500
2	Sabalan (Booshli)	16.48	240	1500–2500	550
3	Sareine	16.65	140	500–1000	550
4	Damavand	5.11	190	2000–3000	550
5	Sehand	7.6	160	1500–2500	11,000
6	Khoy–Maku	30.40	170	2000–3000	6,200

Fig. 6. The Meshkinshahr area in Sabalan region which has been selected for the first exploration drilling site.

Fig. 7. Geothermal prospects of Iran.

Table 11
Iran's biomass type

Municipal solid waste				Quantity of raw material available		15.3 million tonnes
Forestry/wood processing				Quantity of raw material available		
Capacity of project (kW)	Percentage of progress until 2005	Utilize	Start	Region	Technology	Project
–	100	2003	2003	Tehran	SPE	Fuel cell
1.2	100	2005	2005	Taleghan	Fuel cell	Buying of fuel cell (2.1 kW)
–	100	2005	1996	Taleghan	Fuel cell	Hydrogen and fuel cell pilot
25	60	2007	2006	Taleghan	Fuel cell	Buying of fuel cell (25 kW)
5	15	2009	2006	Taleghan	Fuel cell	Buying of fuel cell (5 kW)
–	10	2009	2002	All over the country	Fuel cell	Fuel cell committee
200	55	2007	1996	Taleghan	–	Hydrogen pilot
0.01	100	2005	2002	Tehran	Energy reservation	Installation of vanadium cell
1	25	2006	2005	Taleghan	Energy reservation	Manufacture of vanadium cell
50	–	2008	2005	Taleghan	Energy reservation	Hydrogen pilot
–	100	2000	1998	All over the country	Feasibility study	Biomass
600	100	2005	2004	Shiraz	Feasibility study	Feasibility study for installing of biomass power plant
400	100	2005	2003	Mashad	–	
10,000	10	2007	2005	Rasht	Feasibility study	Feasibility study for installing of biomass power plant
–	–	2009	2006	All over the country	Using of biomass	Feasibility study for biomass
24	100	2000	1997	Arak	Production	Project of biogas in Saveh
2	1	2006	2004	Mazandaran	Using of biogas	Installation of biogas units in rural regions

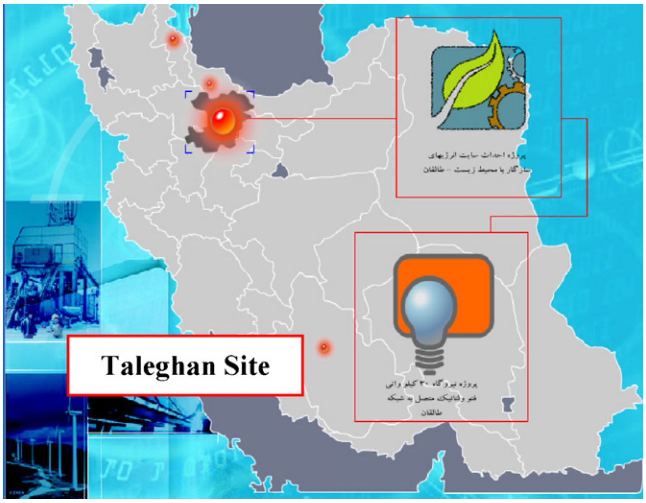

Fig. 8. Hydrogen power plant installed at Taleghan-Iran.

Sabalan. Damavand field is another high enthalpy location which has been earmarked for future activity. One of the strategic future tasks in surface and drilling exploration in 14 geothermal targets (see Fig. 7) [7–9].

5. Biomass, biogas, hydrogen energy and fuel cell

As the world reconsiders its energy options in light of the sources of greenhouse gasses, hydrogen power has been discussed more and more as a viable non-polluting means to achieve goals set by the Kyoto protocol. Pertaining mostly to the transportations sector, hydrogen fuel cells have received significant attention and undergone extensive research. A renewable energy system using hydrogen will not produce any pollution. It is possible to eliminate toxic emissions from cars by replacing the internal combustion engine with hydrogen fuel cells. Hydrogen cars produce only water as exhaust. Hydrogen is a harmless fuel, which can be produced from crude oil in refineries and is the least expensive fuel in Iran. Hydrogen production from natural gas present in oil fields can be used as an economic method for hydrogen production. Despite abundance of hydrogen and serious environmental consequences of fossil fuels, no regular plan has been made to use it. The greenhouse gases are not poisonous per se, but their high concentration in atmosphere will cause global warming. Using hybrid cars (that run on both electricity and gasoline) was a temporary remedy which only postponed global and regional environmental and energy crises. Biomass, in the energy production industry, refers to living and recently living biological material which can be used as fuel or for industrial production. Most commonly biomass refers to plant matter grown for use as biofuel, but also includes plant or animal matter used for production of fibers, chemicals or heat. Biomass may also include biodegradable wastes that can be burnt as fuel. Table 11 shows Iran's biomass type. Taleghan site (see Fig. 8), could give us sufficient energy for direct use of hydrogen energy.

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